NAVIGATING THE OPEN-SOURCE ECOSYSTEM

Mike May, S.J.
Saint Louis University
Department of Mathematics and Statistics
221 North Grand Blvd
St Louis, MO 63108
mike.may@slu.edu

Introduction: This paper looks at open-source course material, sometimes called Open Educational Resources (OER) from the viewpoint of an instructor trying to effectively incorporate materials into a course. As such, it categorizes materials from a framework that I would use for incorporating of any kind into a course, first a textbook, then supplemental material, then activities, then a homework system. Issues to deal with include ease of use, availability of support, and being able to navigate the political waters that always accompany change of any kind.

Background and definitions: It is useful to start with some definitions. An **Open Educational Resource** (OER) is free and allows the user, the five Rs. It allows the user to Retain, Reuse, Revise, Remix, Redistribute the material. Note that it is not the same as being in the public domain. In particular, the most common licenses carry restrictions like Attribution, Share Alike, Non-Commercial. (You must leave the author's name attached to the work and cannot claim it as your work. If you make a derivative work, it must carry the same restrictions. You may not sell the work, or you may not charge more than a minimal copying fee.) While the licenses come in several flavors with the most common being one of the Creative Commons Licenses. (<https://creativecommons.org/share-your-work/cclicenses/>). In this paper we will not hold to a strict definition of OER, but will include materials that can be freely used by instructors in a non-profit setting.

It is worthwhile to think about why people would create work under an open license rather than selling it. The background justification is the mantra of Linux, "none of us is as smart as all of us". Harnessing the work of a group of people means everyone has a product that is better than what anyone could produce individually. It is also possible to build a community of users with a free product that might not be possible with a commercial product. Some people create OER material because they want to remove the cost of textbooks from their students' lives. They are concerned that the price of textbooks is a barrier to access for their students. This is the stated motivation behind the open textbook initiatives of several states. Some people create OER materials because they want their materials to be available and cannot reach an agreement with a publisher. That can be because the publisher wants to move on to a new product. (Strang Calculus, was copyrighted but after the publisher moved on to a new text, the book was rereleased through MIT open courseware.) [<https://ocw.mit.edu/courses/res-18-001-calculus-fall-2023/pages/about/>]. One might also go OER if the authors want to use a different

approach from the commercial publishers. (Active Calculus (<https://activecalculus.org/>) and Business Calculus with Excel (<https://maymk.github.io/ExcelCalculus/2024/ExcelCalculus.html>) are different in approach from standard texts. Pedagogically, an author may want to focus the course using a non-text open-source project. (E.g Sage, R, S, DOENet.)

A Word of Caution: In looking at OER textbooks, it is worthwhile to start with a word of caution. Many projects are turned down by publishers because they are of a poor quality. Publishers have editor, focus groups, and marketers. They have the latest software for layout and design. For the most part, publishers produce books that are technically high quality. Open-source materials may be more uneven. Additionally, publishers have customer service representatives. Using OER may mean that the instructor needs to provide the support. Finally, there may be legitimate concerns from administrators. They may be concerned with legal and copyright issues. An institution may have entered an exclusive marketing relationship at an institutional level.

Organization of the rest of the paper: The rest of this paper is a roadmap for instructors of the profile I usually encounter at ICTCM who are interested in using open-source materials. In order, I will address concerns of instructors who want to:

- Find a book that is free to my students, and not much more work for me
- Find auxiliary material to supplement my course
- Find a homework system I can use with a free book
- Integrate free material into my LMS
- Convince my administration/department that free books are viable
- Write an open textbook
- Things on the horizon

Just Find Me a Free Textbook: There are a lot of free textbooks available online. Some of them have serious defects. A good first strategy is to look for sources where the textbooks offered have been peer reviewed. You want someone other than the author telling you the book is worthwhile.

There are several sources I would recommend. A first collection is OpenStax (<https://openstax.org/subjects/math>). OpenStax is connected to Rice University. It is a larger project that is providing open-source textbooks across a broad range of topics. The effort is motivated to remove the cost of textbooks as a barrier to access to education. The math textbooks in OpenStax only go up to Calculus and they tend to be traditional in flavor. Among open-source repositories, OpenStax comes the closest to providing the services one might expect form a publisher. The texts are peer and editorially reviewed. The volumes I looked at had LMS cartridges, PowerPoint slides and instructor solution manuals. They provide alignment guides to the common core and to AP standards. I was also able to find complete sets of YouTube videos to go with the course. OpenStax also works with partner companies, so instructors can get added services for a fee. Some sample texts include:

- Calculus: https://openstax.org/details/books/calculus-volume-1
- College Algebra: https://openstax.org/details/books/college-algebra-corequisite-support-2e
- Business Statistics: https://openstax.org/details/books/introductory-business-statistics-2e

OpenStax is the place I would start with if I was looking for a traditional text, wanted all the pieces that go with a textbook, and I wanted to do it as efficiently as possible. It would be my recommendation for most people attending ICTCM.

Another collection is LibreTexts (<https://libretexts.org/ >) This is part of a project centered at University of California Davis. Some support comes from the state of California with the stated goal of removing textbook costs as a barrier to access to education. One way that this collection differs from the others is the practice of converting open textbooks to their format without the knowledge of the original authors. It should be noted that this is explicitly allowed under most open-source licenses. It also means that as with any conversion process, you may not have the most recent version and may have lost features that the author had inserted. It is designed to make it easy for an instructor to create an OER product. The ease of creation is both a strength and a weakness. A lot of material is available. It does not seem to use any peer review process. Some of the materials look like they may have copywrite issues. We will return to LibreText when looking for supplements.

My favorite source is the American Institute of Mathematics, or AIM. It lists its criteria for review. Their books cover a broad range of mathematical levels, from developmental math to senior level courses. Most of the books have source code that can be used if you want to make and use a modified version of the text.
A list of texts is at (<https://aimath.org/textbooks/approved-textbooks/>)
Some of my favorites include:

- College Algebra: https://yoshiwarabooks.org/mfg/MFG.html
- Business Calculus: https://mathstat.slu.edu/~may/ExcelCalculus/LandingPage.html
- Active Calculus: https://activecalculus.org/
- Introduction to Proof: https://gvsuoer.github.io/sundstrom-textbook/frontmatter.html

In the spirit of full disclosure, the textbook I authored is on the list.

I want to conclude this section by listing some other collections of open textbooks that I have found useful.

The Open Textbook Network https://open.umn.edu/opentextbooks/ The Open Textbook is sponsored by the University of Minnesota. It has a broad collection of texts but does not seem to be peer reviewed.

The University of Lethbridge https://opentext.uleth.ca/ also has a list of textbooks that they use.

The site OpenIntro: https://www.openintro.org/ is noteworthy since it is mainly dealing with statistics.

Finally, the text Calculus for Biological Scientists: https://www.math.colostate.edu/~shriner/meta_frontmatter.html was intriguing to me.

I Have a Textbook, Help Me Find Supplemental Material: Once again, the advice starts with looking for collections of materials that other people have found useful. I will break the supplemental material into several segments: auxiliary texts, sections for particular material, teaching materials, and extra activities.

For auxiliary texts, one of the nice features of open textbooks, is they are easy to use as a second text when students want an alternative presentation. You may have students who would benefit from a presentation that is more or less theoretical, applied, active, or … from the approach you take with most students. Simply follow the instructions above for finding an open text and add a second text to your syllabus.

The second situation is when I want material that is assumed for a course but not explained in the textbook. This corresponds to all the times the instructor says "recall, as you learned in a previous course." I want to add a particular section or two from another textbook. In the past I would go to one of the following sites:

- Kahn Academy: https://www.khanacademy.org/
- Purple Math: Math https://www.purplemath.com/modules/index.htm
- Paul's lecture notes: https://tutorial.math.lamar.edu

It should be noted that these sites tend to be copyrighted but allow for links. Formally, they are not open-source. They tend to be ad supported.

One can also go to several sites that accumulate open-source materials like MERLOT, and MIT Open courseware. It should be noted that MERLOT requires a lot of additional searching and MIT open courseware is designed for students at MIT.

- MERLOT: https://www.merlot.org/merlot/advSearchMaterials.htm
- MIT Open courseware: https://ocw.mit.edu/search/?d=Mathematics&q=mathematics

My current favorite strategy is to use LibreText, which lets you search through sections of its collection of books. In teaching calculus II, I needed to review long division of polynomials and support students who claimed to have never seen it. The search in Math Objects for "Long division of polynomials" gave me sections from texts in college algebra and precalculus on the subject matter.

For teaching materials, the best strategy is to look for the communities that form around open textbooks. Search for hubs, where material is accumulated.

The last type of supplement is a computer visualization. The best known of these are activities with GeoGebra and Desmos.

GeoGebra is a collection of tools to mix together and experiment with Geometry, Algebra, Spreadsheets, Computer Algebra, and 3D graphics. More to the point od this paper, it is a repository of over a million learning objects available under a creative commons open-source license. They provide a guide for finding resources. (<https://help.geogebra.org/hc/en-us/articles/8823429816221-Find-GeoGebra-Resources>). My advice is to search (< https://www.geogebra.org/materials>), then look for books, which are collections of applets that have been put together.
Some interesting books include:

- Brzezinski Calculus https://www.geogebra.org/m/YpqytNph
- Mike May Calculus https://www.geogebra.org/m/JDxzvGxD
- College Algebra – All Units https://www.geogebra.org/m/AzB6fFEb
- Mike May College Algebra https://www.geogebra.org/m/ePHG2tA4

Like any library search, part of the game is to find favorite authors and search for their works. I recommend Kuhlmann and Brzezinski. GeoGebra has many other features but that is matter for another Day.

Any discussion of GeoGebra is likely to get paired with a discussion of Desmos. (<https://www.desmos.com/>). Most people (including myself) find Desmos easier to use as a graphing calculator. It has a 3D grapher in beta (<https://www.desmos.com/3d>). You can make sophisticated demonstrations, but I cannot find a good repository of materials. It should also be noted that Desmos applets do not seem to have an open-source license.

Both GeoGebra and Desmos have a classroom mode where files can be shared and assigned.

For courses that deal with surfaces rather than curves, I would recommend CalcPlot3D (<https://sites.monroecc.edu/multivariablecalculus/>). It is licensed under creative commons with the note that you should refer back to the project site.

I Have a Textbook, Now Find a Homework System I Can Use with a Free Book:
Many instructors have been sold on the value of an automated homework system. My students need to do homework to succeed. Optimally they should get immediate feedback. My standard is that I want a system where most questions are free response, algorithmically generated, and intelligently graded. The system should only occasionally use multiple choice. Each student should get an individual version of the question. The grader should understand math, "1+x" is the same thing as "x+1".
I have found the following open source homework systems:

- WeBWorK https://openwebwork.org/
  Requires setting up a server
- MyOpenMath https://www.myopenmath.com/
  Inspired in part by WeBWorK – There was a workshop on setup at the last ICTCM and I would anticipate this happening at future conferences.
- Ximera https://ximera.org/
  A product of Ohio State and Florida. It does not seem to have extensive library. It is designed for authoring problems.
- LibreText also has a homework system, but I am not familiar with it. The online description indites it can import problems from MyOpenMath and WeBWorK.

Talking about homework systems, it is worthwhile to note that you need to think about technical support, or the lack thereof. It leads to different approaches depending on the user's situation.

The first homework system to discuss is WeBWorK: (<https://openwebwork.org/>) It is the workhorse used by most large R1 research universities. It was originally designed at the University of Rochester. It has a large library of problems. Since it started at an R1 school it has the richest problem set at calculus and above. It has sets of problems from many popular books. I note however that I have pulled problems from a library for middle school math. The model for its use is for a school to set up its own server to run the program. There is an active users group that provides support.

Some people may be interested in using WeBWorK, but not have the IT resources to run a server at their school. There are some commercial add-ons that will host WeBWorK for a fee. The two service I know are:

- Runestone hosting: https://blog.runestone.academy/pages/webwork.html
  Vanilla hosting, $120 per course (capped at 60 students)
- Edfinity https://openwebwork.org/
  With bells and whistles ($25-$39 per student)

The other homework system to mention is MyOpenMath.
(<https://www.myopenmath.com/>). It was inspired in part by WeBWorK. Its library is strongest in Arithmetic through Calculus. MyOpenMath is hosted without charge, so it has a shallower learning curve than WeBWorK. Schools can set up their own server and

run it locally. The technology is referred to as IMathAS and is used by several commercial systems. Some examples include:

- Lumen Learning https://lumenlearning.com/
  (Courses about $35 per student)
- xyzhomework https://www.xyzhomework.com/
  ($45 for one year with xyztextbook, for 3 years with OpenStax,)

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I **want to Integrate OER material into my LMS**: It is noteworthy the OpenStax provides cartridges for LMS integration. I have WeBWorK on Runestone Hosting integrated into Canvas. Looking at the apps available on my schools Canvas installation I found: OER commons, MyOpenMath, MERLOT, GeoGebra, Open Education Search, and Sage.

I want to convince my administration/department that free books are viable: The fact that California has made a push to use OER materials at a state level and the foundation support for OpenStax is strong evidence that OER is with us to stay. A list of schools using OER materials helps. The biggest problem is that there is work in any transition and it needs to be supported.

I want to write my own open textbook: Understand that it is more work than you think it will be. But it can be rewarding. The first step is to have a reason to put in the effort for which you probably will not get paid. The reason can be that you want to save your students the cost of a textbook, or that you are unsatisfied at the collection of books that are available. Produce a draft and get people to critique it. At an organizational level you need to decide the format you will write in. Do you want to put a print book on the web or produce a web format that can be turned into a book? There are two authoring systems that I have found:

- LibreText seems designed to put a print text on the web.
- PreTeXt (<https://pretextbook.org/ >) seems to be designed to think in terms of web projects.

What other open-source software tools should I know about: They might be useful but are probably beyond the needs of typical ICTCM participants.

- Sage: https://www.sagemath.org/ sage is a computer algebra system. (Think Mathematica or Maple.) It has a lot of computational power. I have seen it used most effectively in abstract algebra courses. It has a nice set of commands in cryptography.
- Octave: https://octave.org/ Would be described as in the same equivalence class as MatLab. Likely to be seen in engineering departments or math for engineers.
- R: https://www.r-project.org/ R is a language for doing statistics. It is often paired with RStudio. It is used both n education and in real world statistical work.

- LibreOffice: https://www.libreoffice.org/ LibreOffice is an open-source clone of Microsoft Office.
- Moodle: https://moodle.org/ Moodle is an open-source program in the same equivalence class as Blackboard.

There are a couple of projects that I put in the category of things that are percolating. They have promise but are probably not developed enough for the typical ICTCM participant to use.

Runestone: https://runestone.academy/ns/books/index has its roots in computer science Most popular courses are Discrete Mathematics and Active Calculus.

- Runestone sample book - Abstract Algebra: https://runestone.academy/ns/books/published/PTXSB/sample-book.html
- Discrete Math: https://runestone.academy/ns/books/published/dmoi/dmoi.html

I would describe Runestone as an LMS on steroids. It has books and assignments, but it also records all the computer actions of the students.

DOENet: https://www.doenet.org/ or Distributed Open Education Network is designed for instructors who want to run experiments on the impact of different learning treatments on student learning.